# The Binary Evolution of the subdwarf B star PG 1336-018

H. Hu[1,2], M. Vuckovic[2], G. Nelemans[1], P. Groot[1], C. Aerts[1,2]

*1) Department of Astrophysics*
*Radboud University Nijmegen*
*The Netherlands*

*2) Institute of Astronomy*
*Katholieke Universiteit Leuven*
*Belgium*

## Abstract

We present a study of possible progenitors of the pulsating subdwarf B (sdB) star in the very short-period, eclipsing binary PG 1336-018. Using results from detailed stellar evolution models, we reconstruct the common envelope (CE) phase in which the sdB star was formed. Our results constitute a fruitful starting point for our seismic work on this star, which is based on high-precision VLT photometry and spectroscopy of this target star.

## Introduction

Subdwarf B stars are core-He burning stars (~0.5 $M_{\odot}$) with an extremely thin H-envelope (< 0.02 $M_{\odot}$). It is not clear how they manage to loose almost their entire H-envelope when the core is close to He-ignition, i.e. near the tip of the RGB. The fact that many sdB stars are found in binaries suggests that Roche-lobe overflow may play an important role in their formation. To test this, and other formation channels, a detailed investigation of the sdB interior structure is needed. Since pulsations have been detected in a significant fraction of sdB stars, we can use asteroseismology to test the outcome of sdB formation channels.

## PG 1336-018

A promising candidate for a detailed evolutionary and asteroseismic analysis is the pulsating and eclipsing sdB star PG 1336-018. The period of the orbit is extremely short at 0.101016 d [1]. Our goal is to restrict the initial orbital parameters of the system's progenitor.

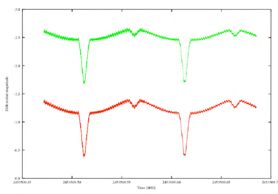

Figure 1. ULTRACAM-VLT g' and r' band lightcurves showing the eclipsing and pulsating nature of PG 13336-018.

## The pre-CE binary

The range that a giant's core mass and radius can have for the core to still ignite He after loss of the envelope, has been calculated by Han et al. [2] as a function of ZAMS mass. We use their results to calculate the pre-CE orbital period as a function of the sdB progenitor ZAMS mass, see fig. 2. We also studied the effect of the companion's mass on the intial period. Since the influence is small we take $M_2$ = 0.15 $M_{\odot}$ here, as proposed by Kilkenny et al. [1].

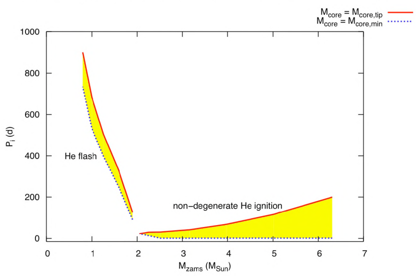


Figure 2. The pre-CE orbital period as a function of the sdB progenitor ZAMS mass. Model assumptions are solar metallicity, convective overshooting and Reimer's wind mass-loss. Furthermore, it is assumed that the companion has not accreted any mass.

## The CE Phase

During the CE phase the two stars spiral inwards due to friction. It is commonly assumed that the orbital energy released in the spiral-in process is used to eject the CE with some efficiency $\alpha$. The binding energy of the envelope can be expressed as $GMM_{env}/\lambda R$, with $\lambda$ depending on the stellar density distribution. We calculated $\alpha\lambda$ as a function of the ZAMS mass (fig. 3).

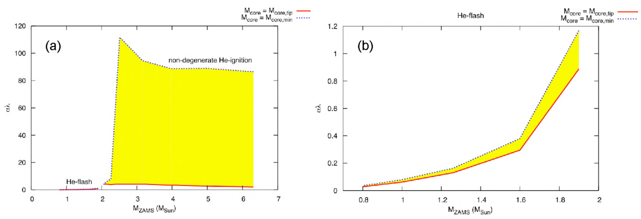


Figure 3. The parameter $\alpha\lambda$ as a function of the sdB progentior ZAMS mass. We calculated $\lambda$ using stellar evolution models, and found $\lambda$ ~ 0.4 - 1.0 for this mass range. (a) Notice that $\alpha$ takes unphysically high values in the case of non-degenerate He-ignition. In (b) we zoom in on the He-flash region, which corresponds to core masses of ~ 0.4 - 0.5 $M_{\odot}$, and find more realistic values for $\alpha$.

An alternative algorithm for the CE evolution is provided by Nelemans et al. [3], and assumes that the specific angular momentum carried away by the ejected envelope is $\gamma$ times the specific angular momentum of the initial binary. Our results using the $\gamma$-algorithm are shown in fig. 4.

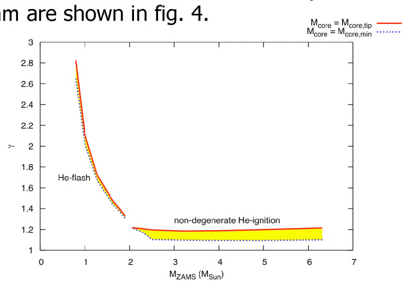


Figure 4. The parameter $\gamma$ as a function of the ZAMS mass.

## Conclusions

If the CE phase is described by the $\alpha$-formalism, we can reject the non-degenerate He-ignition scenario for PG1336-018. We then expect the sdB mass to be between 0.4 - 0.5 $M_{\odot}$, and the sdB progenitor ZAMS mass to be < 2 $M_{\odot}$. The results for the $\gamma$-algorithm are not exclusive, and a broader mass range is still possible in this case. We have now made a first selection of possible progenitors, which we will use for a detailed evolutionary and seismic study in future work.

## References

[1] Kilkenny, D., O'Donoghua, D., Koen, C., Lynas-Gray, A.E., van Wyk, F., Mon. Not. R. Astron. Soc. 296, 329-338 (1998).
[2] Han, Z., Podsiadlowski, Ph., Maxted, P.F.L., Marsh,T.R., Ivanova, N., Mon. Not. R. Astron. Soc. 336, 449-466 (2002).
[3] Nelemans, G., Verbunt, F., Yungelson, L.R., Portegies Zwart, S.F., A&A 360, 1011 (2000).

hailihu@astro.ru.nl